THE VERTICAL FIBER HIDE DEFECT: TRANSMISSION TO PROGENY AND RELATION TO REPRODUCTIVE FAILURES IN CROSSBREEDING TEST*

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Abstract

Studies over the past 20 years have shown that the vertical fiber hide defect, which causes moderate to extreme weakness in leather, occurs much more frequently in Herefords than in the other two major cattle breeds examined so far. Evidence from several tests, including a recent hide biopsy study of twin Hereford and Holstein cows, supports the theory that this defect is a genetically controlled trait. We have now extended the biopsy study to include 76 progeny of these same cows, produced by reciprocal crossbreeding through three calvings, to test the incidence of the defect in known crossbreds. Although 13 of the Hereford dams and one of the Hereford sires carried the defect, only one of the calves was found to be defective. Samples were not available from three of the eight sires. Apparently the defect does not commonly occur from this type of crossbreeding.

Analysis of the calving records from the crossbreeding test revealed preliminary evidence which, if confirmed by further testing on a larger scale, may have serious economic implications to the beef cattle industry. The Holstein cows produced a live calf crop of 86 percent of expected pregnancies and the normal Herefords produced 90 percent. However, the 13 defective Herefords produced only 70 percent and the five with extreme defect only 53 percent. Most of the Hereford failures were due to stillborn calves, especially from one pair of defective twins.

Introduction

Side leather tanners in this country have long been familiar with the localized weakness in certain hides caused by the vertical fiber defect, also known as "pulpy butt" or "pulpiness." Many have tended to disregard such naturally occurring

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defects in the face of more threatening financial crises from other sources, but the problem still remains as a serious challenge to leather quality. Unfortunately, neither the true incidence nor the total extent of economic losses involved has ever been established.

The defect was first reported from Australia in 1958 (1) but, since then, all of the published research has come from the United States: from the Tanners' Council Laboratory (2–5), from this Center (6–9), and from our leather industry (10). This national concern reflects the dominance of the Hereford breed among our commercial beef cattle. After Tancous *et al.* (2, 3) had shown that the defect was inherent in raw hides there was some attempt (4, 5) to estimate the incidence in commercial hides, but this has not been conclusive for known specific breeds other than Hereford (7–9) and Holstein (8). Incidence of the defect can vary widely in individual lots of hides and is thought to involve about five percent of normal tannery production (3), or from six percent (5) to 18 percent (4) of all Hereford hides. A tabulation of all published data now indicates an incidence of about 13 percent among more than 3,400 hides either known or assumed (by hair color pattern) to be Hereford. There was also an incidence of about 0.8 percent among more than 1,500 hides either known or assumed to be Angus or Holstein. No other breed types were studied.

As its name suggests, the defect is characterized by abnormally arranged collagen fibers in the reticular (corium) layer, wherein the fibers are loosely oriented nearly perpendicular to the hide surface instead of being compactly interwoven at lower angles. The publications cited above give further descriptions of microstructure and the variability of physical properties at different hide locations. The defect occurs in known Hereford bulls and steers (9) and in known Hereford heifers and cows (8). Heritability was first suggested by a concentration of the defect in a few sire groups in a sire performance test (7); an estimate of 30 percent heritability was calculated (8, p. 279). This hypothesis was supported by results of a study of twin cattle (8) and by a very high incidence from an inbred herd (9).

Thus, reduction or elimination of the defect is a breeding problem, and the present study was undertaken in 1971 to seek further breeding information from the continuing aspects of the twin cattle test previously mentioned (8). In that test, 30 Hereford and 30 Holstein cows were utilized for a reciprocal crossbreeding study through three calvings to evaluate the interaction of genetic and environmental (feed) factors. We obtained hide biopsy samples from five of the eight sires involved, and from about half of the resulting progeny at one year of age, taking care to select all that were available from the 13 Hereford cows previously found to have the defect. We also tabulated the detailed calving records as the test progressed. Data on transmission of the defect and on the surprising number of reproductive failures among defective cows are presented below in considerable detail in order to make all of the information available. It is difficult to interpret the results because of the small size of the test and incomplete data on the bulls, and especially because it involves a number of pairs of identical twins. Inclusion of all the details will permit others to reevaluate the results.

Experimental

Test Design

The animal study was conducted at the University of Wisconsin under the direction of Prof. E. R. Hauser and with the cooperation of the Agricultural Research Service (now designated Federal Research, Science and Education Administration), U. S. Department of Agriculture. The experimental cows were 15 sets of Holstein twins, 14 sets of Hereford type and two unmatched Herefords, all born in 1969. Description and assignment of diets to the cows were given previously (8). The cows were bred by artificial insemination at every heat period after 15 months of age; the Herefords were bred to four commercial Holstein bulls and the Holsteins to four commercial Hereford bulls. The same breeding schedule was used for each of the three calvings. Calves received a high-energy feed until they were weaned at eight months, then a growing diet to one year, and finally a high-energy feed again until slaughter at 18 months. Most of the calves were black with white faces.

Biopsy Procedure

Biopsy samples consisted of small plugs of full-thickness hide 3/8 inch in diameter. They were removed by means of an automatic biopsy gun (11) from the rump area, approximately ten inches from the tail root and ten inches from the backbone line, of each selected calf at one year of age. The samples were put into containers of ten percent neutral formalin solution* and shipped to our laboratory, where they were cut in half in the plane of hair follicles. We also tried to obtain hide samples from the eight bulls involved in the breeding. Unfortunately, two of them had already been slaughtered and a third one could not be traced. Through the cooperators listed in the Acknowledgments section we received irregular hide samples, surgically removed from the rump area of the five available bulls, from resident veterinarians. These samples were handled in the same manner as the others.

Histology

Cross sections perpendicular to the upper surface were cut from each sample on a freezing microtome at 50 microns. The sections were stained with hematoxylin and eosin and evaluated microscopically as previously described and illustrated (8). Fiber structure in the corium was classified as normal (N) if the fibers were compactly interwoven and uniformly inclined at angles below about

*A 1:10 dilution of commercial formaldehyde solution to which an excess of $CaCO_3$ is added, giving a formaldehyde concentration of 3.7 to 4.0 percent.

60° from horizontal. If there was a variable looseness of weave and the fibers tended to be nearly upright in localized areas, the sample was classified as intermediate (I), which is considered to be a moderate form of the vertical fiber defect. If the fibers were consistently loose and upright, with little interweaving, this represented the vertical (V) or extreme degree of vertical fiber defect. The distinction between normal and intermediate classifications is often a difficult subjective decision and is aided by examination of additional samples.

Test Hides and Leather

Hides from six of the crossbred progeny (including three cases of doubtful biopsy results) and from one of the defective Hereford cows were obtained in the salted condition to permit further testing for confirmation of biopsy diagnoses. The left sides were examined directly while the right sides were processed by a cooperating tanner into upper leather to the crust stage. For testing, the sides were sampled at 12 locations in a rectangular pattern that we had used before (9, Fig. 1). Microscopic evaluation of fiber structure and standard physical tests were performed on crust samples from each location by the methods specified previously (9). All data were carefully evaluated to classify the hides accurately. Only one of the three doubtful biopsy results was confirmed to be defective (I) while the other two were considered normal. Results for the remaining four hides agreed with original biopsy diagnoses. Detailed results are not reported here.

Results

Biopsy Results for Progeny

Due to budgetary limitations we were able to sample only 76 of the 148 live calves produced from the three crossbred calvings of the 60 test cows. We tried to select a representative group but gave preference to cows previously found defective (8). Table I contains the biopsy results for 21 of the 24 available Holstein-Hereford calves from ten Hereford cows with the defect. Of the three other defective cows not listed, two had no live progeny. All of the calves listed had normal fiber structure.

Table II lists the biopsy results for 18 calves out of 27 available from ten Hereford cows without the defect. Progeny from the seven other normal Herefords were not sampled. Hide samples from all of these calves were considered normal. Table III contains the results for 37 Hereford-Holstein calves from 19 Holstein cows with normal fiber structure. The remaining 11 cows were not represented. Thirty-six calves were considered normal but one (from cow 216) had intermediate fiber structure and was thus defective.

To summarize the biopsy results: all of the progeny tested had normal fiber structure except for one considered intermediate. This case might be explained by the fact that the sire (No. 5) had defective fiber structure. However, it can

TABLE I

EVALUATION OF FIBER STRUCTURE IN SELECTED PROGENY OF HEREFORD COWS WITH DEFECT

Hereford Dams*		Holstein Sires*		Fiber in Progeny†		
No.	Fiber	No.	Fiber	First	Second	Third
215	I	1	—	N	N	N
236	I	4	N	N	N	N
238	I	2	N	N	N	N
239	I	2	N	N	N	—
241	V	4	N	—	—	N
244	V	2	N	N	N	—
245	I	2	N	N	—	—
250	V	3	N	N	N	—
251	V	3	N	N	N	—
265	I	4	N	N	N	—
Totals (24 available)				9N	8N	4N

*No. refers to animal identification. Fiber refers to fiber structure in biopsy samples: N — normal; I — intermediate; V — vertical, as explained in Experimental section.

†Results through three calvings occurring mostly in 1971, 1972, and 1973, respectively. Dash means not available or not selected.

TABLE II

EVALUATION OF FIBER STRUCTURE IN SELECTED PROGENY OF HEREFORD COWS WITHOUT DEFECT

Hereford Dams*		Holstein Sires*		Fiber in Progeny*		
No.	Fiber	No.	Fiber	First	Second	Third
226	N	4	N	N	N	N
227	N	4	N	N	N	N
242	N	1	—	—	N	—
247	N	3	N	—	N	N
248	N	2	N	—	—	N
252	N	3	N	N	N	N
254	N	3	N	—	—	N
259	N	1	—	—	—	N
262	N	1	—	N	N	—
263	N	1	—	—	—	N
Totals (27 available)				4N	6N	8N

*See footnotes in Table I for explanation.

TABLE III

EVALUATION OF FIBER STRUCTURE IN SELECTED PROGENY OF HOLSTEIN COWS WITHOUT DEFECT

Holstein Dams*		Hereford Sires*		Fiber in Progeny*		
No.	Fiber	No.	Fiber	First	Second	Third
202	N	8	N	N	—	N
203	N	8	N	N	N	N
206	N	5	I	N	—	—
207	N	5	I	N	N	N
208	N	7	—	N	N	N
209	N	7	—	N	N	N
211	N	5	I	N	N	N
213	N	8	N	—	—	N
216	N	5	I	N	I	N
217	N	5	I	—	N	—
220	N	6	—	—	N	—
221	N	6	—	—	N	—
228	N	6	—	N	N	N
229	N	6	—	N	—	—
231	N	7	—	—	—	N
233	N	6	—	N	N	N
235	N	8	N	—	—	N
257	N	8	N	N	—	N
261	N	6	—	—	—	N
Totals (52 available)				12N	10N 1I	14N

*See footnotes in Table I for explanation.

be seen from Table III that ten other progeny from this same sire were normal, and Table I shows that 21 progeny of defective dams were normal. These limited data preclude any assessment of the mode of inheritance of the defect in this type of crossbreeding.

Analysis of Calving Records

Because we were seeking all the breeding information we could get from the test at Wisconsin, detailed calving records were accumulated during the test and were later reassembled according to breed and fiber groups. Records for the Hereford cows with the vertical fiber defect are shown in Table IV, including designations of identical twin pairs and the fiber classifications of the Holstein sires where available. Cows with the intermediate (I) defect had 18 percent failures due to one stillborn and three conception failures. However, cows with extreme (V) defect had 47 percent failures due to a high rate of stillborn calves, including one set of stillborn twins. Twin cows 240 and 241 were mainly responsible for the poor performance of this group. It is impossible to determine, at this

TABLE IV

CALVING RECORDS OF HEREFORD COWS WITH DEFECT

Her.* Cows	Feed Level	Holstein Sires		Calving Results†			Totals	
		No.	Fiber	First	Second	Third	Alive	Failure
Intermediate Fiber (I)								
214(1)‡	High	1	—	S	A	A	2	1
215(1)‡	Low	1	—	A	A	A	3	0
236(2)	Low	4	N	A	A	A	3	0
237(2)	Low	4	N	O	O	Out	0	2
238(3)	Low	2	N	A	A	A	3	0
239(3)	Low	2	N	A	A	A	3	0
245	High	2	N	A	O	Out	1	1
265‡	High	4	N	A	A	A	3	0
Totals							18	4
% of 22 possible							81.8	18.2
Vertical Fiber (V)								
240(4)	Low	4	N	S	S	O	0	3
241(4)	High	4	N	S	S/S	A	1	3
244	Low	2	N	A	A	A	3	0
250(5)	Low	3	N	A	A	O	2	1
251(5)	Low	3	N	A	A	Died	2	0
Totals							8	7
% of 15 possible							53.3	46.7

*Twin pairs are designated by consecutive numbers, the first of which is an even number. Sets of identical twins are indicated by matching numbers in parentheses.

†Letters mean: A — alive; S — stillborn; S/S — stillborn twins; O — open, failure to conceive on 2 inseminations; Out — cow culled from test; Died — cow died.

‡¾ Hereford, ¼ Shorthorn.

point, whether or not there is a relationship between the hide defect and the poor reproductive performance of these animals, or if other factors are involved. In the absence of other evidence, we feel that there is no justification for excluding any of the data. Corresponding details for the Hereford cows free of the defect are shown in Table V.

Here there was a very normal rate of ten percent failures. Note that some of the Hereford-type cows were not purebred. Corresponding details for the Holstein cows, which were all free of the defect, are shown in Table VI. The overall failure rate for this group was about 14 percent. Although one of the Hereford sires (No. 5) was defective and was involved in the only case of abortion, two other sires were unclassified and it is impossible to interpret a true sire effect.

TABLE V

CALVING RECORDS OF HEREFORD COWS WITHOUT DEFECT

Her.* Cows	Feed Level	Holstein Sires		Calving Results†			Totals	
		No.	Fiber	First	Second	Third	Alive	Failure
224	High	4	N	A	A	A	3	0
226 (6)	High	4	N	A	A	A	3	0
227 (6)	High	4	N	A	A	A	3	0
242 (7)	Low	1	—	S	A	A	2	1
243 (7)	Low	1	—	A	A	A	3	0
246 (8)	High	3	N	A	A	S	2	1
247 (8)	High	3	N	E	A	A	2	1
248 (9)‡	High	2	N	A	A	A	3	0
249 (9)‡	High	2	N	A	A	A	3	0
252	High	3	N	A	A	A	3	0
253	Low	3	N	A	A	A	3	0
254	High	3	N	A	A	A	3	0
258 (10)	High	1	—	A	A	A	3	0
259 (10)	High	1	—	A	A	A	3	0
262	Low	1	—	A	A	A	3	0
263	Low	1	—	S	A	A	2	1
264**	High	4	N	A	A	O	2	1
Totals							46	5
% of 51 possible							90.2	9.8

*See footnote in Table IV for twin designations.
†Letters mean : E — early death within 21 days; others same as Table IV.
‡¾ Hereford, ¼ Charolais.
**¾ Hereford, ¼ Shorthorn.

The reproductive performance data from each of the breed and fiber groups of cows are summarized in Table VII. The normal Herefords compare very favorably with the Holsteins, showing a 90 percent live calf crop and 29 percent of cows with failures compared with 86 and 30 percent, respectively. Combined results for the 13 defective Herefords tell a different story, with only a 70 percent live crop and 46 percent of cows with failures. Such poor performance is economically undesirable since the industry-wide average calf crop is thought to be about 80 percent (12). Our method of expressing the calf crop as percent of expected pregnancies does not quite conform to industry practice. The usual definition of a 100 percent calf crop means one weaned calf per cow per year (12). Our results would be even lower if estimated this way.

Under the assumption of randomized sampling, a statistical comparison shows that the 70 percent calf crop of the 13 defective cows is significantly ($p < 0.10$) less than the 80 percent industry average. However, the assumption of randomization may not hold in this case because of the twin relationships and the exceptional record of one particular pair of twins.

Incidence of Calving Failures

The incidence of the various reasons for reproductive failures are listed in Table VIII for each of the breed, fiber, and feed groups.

TABLE VI

CALVING RECORDS OF HOLSTEIN COWS WITHOUT DEFECT

Hol.* Cows	Feed Level	Hereford Sires		Calving Results†			Totals	
		No.	Fiber	First	Second	Third	Alive	Failure
202	Low	8	N	A	A	A	3	0
203	High	8	N	A	A	A	3	0
206(1)	High	5	I	A	O	O	1	2
207(1)	High	5	I	A	A	A	3	0
208(2)	Low	7	—	A	A	A	3	0
209(2)	High	7	—	A	A	A	3	0
210(3)	Low	5	I	A	A	A	3	0
211(3)	Low	5	I	A	A	A	3	0
212(4)	Low	8	N	S	A	A	2	1
213(4)	High	8	N	A	A	A	3	0
216(5)	High	5	I	A	A	A	3	0
217(5)	Low	5	I	B	A	A	2	1
218	Low	7	—	A	A	O	2	1
219	Low	7	—	E	A	A	2	1
220(6)	High	6	—	A	A	A	3	0
221(6)	High	6	—	A	A	A	3	0
222(7)	Low	7	—	A	A	A	3	0
223(7)	Low	7	—	A	A	A	3	0
228	Low	6	—	A	A	A	3	0
229	Low	6	—	A	O	A	2	1
230	High	7	—	O	O	Out	0	2
231	High	7	—	A	A	A	3	0
232	High	6	—	S	O	Out	0	2
233	High	6	—	A	A	A	3	0
234(8)	High	8	N	A	A	A	3	0
235(8)	High	8	N	A	A	A	3	0
256(9)	Low	8	N	A	A	A	3	0
257(9)	Low	8	N	A	S	A	2	1
260(10)	High	6	—	A	A	A	3	0
261(10)	Low	6	—	A	A	A	3	0
Totals							76	12
% of 88 possible							86.4	13.6

*See footnote in Table IV for twin designations.
†Letters mean: B — aborted; others same as Tables IV and V.

TABLE VII

SUMMARY OF REPRODUCTIVE PERFORMANCE DATA

Categories of Cows			Cows with Failures		Exp. Preg.†	Live Calf Crop‡	
Fiber*	Breed	No.	No.	% of Cows	No.	No.	% of Preg.
N	Hol	30	9	30.0	88	76	86.4
N	Her.	17	5	29.4	51	46	90.2
I	Her.	8	3	37.5	22	18	81.8
V	Her.	5	3	60.0	15	8	53.3
I+V	Her.	13	6	46.2	37	26	70.3

*Fiber structure in biopsy samples: N — normal; I — intermediate; V — vertical, as explained in Experimental section.

†Number of pregnancies expected from breeding inseminations.

‡Live means survived at least 21 days.

TABLE VIII

INCIDENCE OF FAILURES BY BREED, FIBER, AND FEED GROUPS

Types of Failure	Hol. Cows	Her. Cows by Fiber* Class		
	N	N	I	V
Calving Deaths				
Aborted	1	0	0	0
Stillborn	3	3	1	5
By three wks.	1	1	0	0
Infertility	7	1	3	2
Total (%)†	12 (13.6)	5 (9.8)	4 (18.2)	7 (46.7)
Dead at Weaning	3	1	0	1
Calving Deaths				
High Feed	1	2	1	3
Low Feed	4	2	0	2
Infertility				
High Feed	5	1	1	0
Low Feed	2	0	2	2

*Fiber structure in biopsy samples: N — normal; I — intermediate; V — vertical, as explained in Experimental section.

†Percentages based on number of expected pregnancies, Table VII.

The totals are shown for each group, expressed as percent of expected pregnancies. The higher rates of failure for cows with defective fiber structure are obvious, especially for the extreme group (V). The combined rate for all defectives (I +V) was about 30 percent. The numbers of calves that died before weaning are also shown since this is often considered a factor in expressing productivity. Failures are listed separately for the two energy levels of feed given to the cows; trends were not consistent. Ten of the 15 calving deaths, but only two of the 13 cases of infertility, occurred at first calving. There was no evidence of a sire effect to explain the results. Calf crops from the four Holstein sires ranged from 87 to 100 percent with normal Hereford cows. In each case, performance was poorer with defective cows. Calf crops from the four Hereford sires ranged from 83 to 92 percent.

Pathological Abnormalities

In three sets of identical twin Hereford cows there was additional evidence of abnormality besides occasional reproductive failure and the hide defect. The first pair listed were classified as intermediate (I) while the others were vertical (V):

236 — infantile reproductive tract, late first estrus
237 — infertile, twice open
240 — two stillborns, once open
241 — three stillborns including twins
250 — uterine tumors after second calf, open third
251 — death from rectal prolapse after second calf

It is possible that the hide defect may be part of a syndrome also involving the reproductive system and perhaps other organs. This is a common situation in heritable connective tissue disorders (13). The exact circumstances surrounding the calving deaths reported, such as dystocia (14), disease, or other complications, are not known to the authors. The serious implications of these preliminary results certainly warrant confirmation by further investigation on a larger scale.

Conclusions

1. A limited hide biopsy study of crossbred progeny from cows and bulls with and without the vertical fiber defect suggests that the defect does not commonly occur in Hereford-Holstein crossbreds, since only one case of defect, and that moderate, was found.

2. Calving records from the crossbreeding test showed higher rates of calf mortality and conception failures for cows with the defect than for those free of the defect. The possible implications of these results to the beef cattle industry suggest an urgent need for confirmation by a larger test, since the present data are limited both by number and by nonrandom animal relationships.

Acknowledgments

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Discussion

DR. EDWARD MELLON (Consultant): Al, we thank you for a very interesting paper. This paper may be quite frustrating to the tanner because it indicates that there isn't very much that he can do about this problem except complain. I think the results bring out a very important point. Since the defect is also associated with the productivity of cattle, maybe some day the growers will decide that this is not economic for them, and they will gradually cull out the animals that are responsible for transmission of this defect. In these studies, the Hereford cattle were all cows. I would like to ask Al whether the defect also exists in steers?

MR. EVERETT: Yes, both sexes are involved in the defect. There is no evidence of sex linkage.

DR. MELLON: Are there any questions from the audience?

Mr. Stuart Miller (Salz Leathers, Inc.): Are there any other methods used to identify this defect, other than the biopsy?

Mr. Everett: We have tried a lot of other techniques, but none were successful. We have used nondestructive techniques on leather, but you are interested in the live animal?

Mr. Miller: Yes, has anything else worked on the live animal?

Mr. Everett: No.

Mr. Miller: The cattle producers are more interested in reproduction performance. If they take this seriously, we will be flooded with the culls and have a worse problem. The problem should be identified and stopped.

Mr. Everett: This is what we would like to get some attention on. The next step is confirmation. What I have is based on a rather small study.

Mr. Miller: Was this done in conjunction with University of Wisconsin or was this a USDA project?

Mr. Everett: It was a combined project.

Mr. Miller: Is this going to be continued?

Mr. Everett: It was a five-year study that has terminated. What we need is a larger study where we can get biopsy material from all breeding stock. It is a rather simple approach; all you need is a little plug of hide from the living animal. We could then classify all of the breeding stock and have a handle on it. I have approached some of the breeding associations and have obtained biopsy material from some of their prize bulls.

Mr. Miller: Undoubtedly they are more interested than we are; especially from the reproduction aspect. I am sure that the breeding associations for these bulls would be interested.

Mr. Everett: That is why we would like to get more data, so that we could convince more of the breeders that it would be worthwhile to classify their bulls on this defect as well as on others.

Mr. Miller: This information on the reproduction performance, is it being widely distributed to the livestock industry?

Mr. Everett: Yes. We hope to have a story come out in our magazine *Agricultural Research* which gets wide circulation to the grass-roots people, commercial, experiment stations, etc., and hopefully it will be picked up by the trade magazines dealing with livestock interests.

Dr. Mellon: Thank you, Al, for a very interesting paper.